International Journal of Agricultural Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 7, Issue 4, Aug 2017, 401-412

PERFORMANCE EVALUATION OF PORTABLE MODIFIED ATMOSPHERIC PACKAGING UNIT FOR GRAIN DISINFESTATIONS

AMARESH, AMBRISH GANACHARI, DAYANAND KUMBAR, KESHAVALU & BIPIN G

Department of processing and Food Engineering College of Agricultural Engineering, Raichur, University of Agricultural Sciences, Raichur, Karnataka, India

ABSTRACT

The current study was made to evaluate the performance of Portable Modified Atmospheric Packaging (MAP) unit, for storage of bengal gram and sorghum. Flushing pressure and time of gas mixture was optimized, by fixing the responses R1 (CO_2>60%) and R2 (O_2<3%), in the range. The desirability was higher at 5 kg/cm^2 pressure, for 10 second for bengal gram (97.8%) and 2 kg/cm^2 pressure for 20 second, for sorghum (99.2%). Grain or seed quality parameters like insect damage percentage, germination percentage and vigour index, were studied. It was found that, percentage of insect damage increased during storage and there were no evidence of insects in any of the selected grains, till five months of storage. It was observed that, seed germination was highest for bengal gram, stored in PET packets, which is 100 per cent at initial stage and decreased to 97.5 percent, at the end of nine month of storage.

KEYWORDS: Modified Atmospheric Packaging (MAP), Germination Percentage & Vigour Index

Received: May 28, 2017; **Accepted**: Jun 20, 2017; **Published**: Jul 21, 2017; **Paper Id**.: IJASRAUG201751

Original Article

INTRODUCTION

In India, grain production has been steadily increasing, due to advancement in production technology, but improper storage results, in high losses in grains. Post-harvest losses in India amounted to 12 to 16 million metric tons of food grains each year, which is an amount that could feed one-third of India's poor population (World Bank Report, 1999). The monetary value of these losses amounts to, more than Rs 50,000 corers per year (Singh, 2010). During storage, both quantitative and qualitative losses occur due to insects, rodents and micro-organisms. Grain storage plays an important role, in preventing losses which are caused, mainly due to beetles, moths, weevils and rodents (Kartikeyan *et al,* 2009). It is estimated that, 60-70% of food grain produced in the country is stored at home level, in indigenous storage structures. To reduce the storage losses of grains during storage period, modern storage structures and safe and scientific storage techniques are being used, which includes warehouses, cold storages, controlled atmospheric storage, modified atmospheric packaging, spraying the chemicals, controlled atmospheric grain storages, etc.

Modified atmospheres (MA) or controlled atmospheres (CA) offer an alternative to the use of conventional residue producing chemical fumigants for controlling insect pests attacking stored grain, oilseeds, processed commodities, and some packaged foods. These atmospheres also prevent fungal growth and maintain product quality. The MA may be achieved in several ways by adding gaseous or solid CO2, by adding a gas of low O2 content (*e.g.*, pure N2) or by allowing metabolic processes within an airtight storage to remove O2, usually with associated release of CO2. They are collectively known as modified atmospheres‘(Banks and Fields, 1995). Modified atmosphere storage of seeds is a suitable alternative to the use of chemical fumigants and contact

insecticides that are known to leave carcinogenic residues in the treated product (Bailey and Banks, 1980; Shejbal and Boislambert, 1988). MAP is the replacement of atmospheric air in a pack with a single gas or mixture of gases and no further control over its initial composition. The gas composition is likely to change with time due to the diffusion of gases into and out of the product, the permeation of gases in to and out of the pack, and the effects of microbial metabolism and product (Church, 1994). In a CA treatment, atmospheric composition within the treated enclosure is controlled or maintained at a level and duration lethal to insects.

The alteration of CO_2, O_2 and N_2 render the atmosphere’s lethal to pests (Jayas and Jeyamkondan, 2002). Todays world consumers expect that, food products should be free from pesticide or with lower levels of residues (Conyers and Bell, 2007). In addition to this, pressure from the international consumer groups to reduce the chemicals used in food products, makes a non-chemical insect control practice highly desirable (Mitcham *et al.,* 2006). It is demanding to develop the alternative methods that are economically feasible and ecologically adjusted, to control the storage grain insects and fungi (Moreno-Martinez *et al.,* 2000).

Jay and Pearman (1971) reported that, CO_2 is the most important gas among O_2, N_2 and $CO_{2,}$ in controlling insect population within a grain storage system. 100% CO_2 atmosphere was significantly faster than N_2 in controlling adults of *Oryzaephilus Mercator* (Fauvel) and *E. cautella* (Varma and Wahdi, 1978). *Sitophillus* spp. mortality was increased when the level of CO_2 was increased from, 40-75% (Navarro *et al.* 1985). Similarly the mortality increased when the temperature was higher and the exposure time was extended. Elevated CO_2 levels do not adversely affect seed germination and quality (White *et al.* 1990). Bera *et al.* (2008), reported that under modified atmospheric storage (up to 80% CO_2) of paddy seed, with 11% moisture content that could be stored safely, at least up to 12 months, without much reduction in seed viability.

The initial symptoms of carbon dioxide poisoning in insects include a narcotic effect, leading to knockdown, i.e., immobilization of the insects under carbon dioxide-enriched atmospheres (Edwards, 1953). High CO_2 levels cause spiracles to open resulting in insect death from water loss. CO_2 has direct toxic effects on the nervous system of insects. In some cases, CO2 can acidify the hemolymph leading to membrane failure in some tissues (Nicolas and Sillans 1989). Different insect species require different atmosphere for their control. Even within the insect species different strains or populations require different atmosphere for their control depending on their physiology, environmental conditions, temperature and relative humidity (Ramesh babu *et al.* 1989).The effectiveness of modified atmosphere in controlling insects is dependent on various abiotic (gas composition, gas pressure, relative humidity, temperature and length of exposure) and biotic (insect species, life stage and size and distribution of infestation) factors (Jayas *et al.* 1991).

Even though modified atmosphere packaging is the effective method for storing the grains without spoilage more study has not been conducted for optimizing modified atmospheric storage of food grains or seeds to increase the shelf life of the commodities. Hence the attempt has been made to optimize the parameters for the storage of commodities under modified atmospheric condition and following objective were final based on the review of the research work carried earlier.

- To study the physical characteristics of selected food grains.
- Optimization of operating parameters i.e. Flushing pressure and time.
- Evaluation of portable MAP unit for enhancing shelf life of food grains.

MATERIALS AND METHODS

The experiments were carried out in the Department of Processing and Food Engineering, College of Agricultural Engineering, University of Agricultural Sciences, Raichur to study the influence of modified atmospheric packaging conditions on shelf life of selected food grain packaged using portable Modified atmospheric packaging unit.

Selection of Food Grains

An initial survey was conducted to know the major food grain grown in the region, their production and shelf life. Based on the study Sorghum and Bengal gram were selected for the study.

Physical Properties of Selected Food Grains

In order to determine bulk density grain sample was poured in the measuring cylinder of 1000ml capacity and weighed. The bulk density was expressed as the ratio of mass of the sample to the volume occupied by it (Mangaraj *et al.*, 2005).

Particle density was determined using liquid displacement technique (Shepherd, 1986). 50ml of toluene was taken in a graduated measuring cylinder and 20grams of seeds were immersed in the toluene. The amount of toluene displaced was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced toluene gave the particle density.

Porosity of bulk grain was computed from the value of true density and bulk density using the relationship given by Mohsenin (1986) as follows:

$$\in = \frac{(\rho_p - \rho_b)}{\rho_p} \times 100$$

Where, ε stands for Porosity (%), ρ_p is particle density (kg/cm^3) and ρ_b is Bulk density, (kg/cm^3).

Selection of Packaging Material

The packaging materials poly ethylene (PE), polypropylene (PP) and poly ethylene terapthalate (PET) of one kg capacity was used to pack the food grain. The dimensions of the packet were selected based on bulk volume and head space required for filling gas. Thickness of packaging material is determined by using screw gauge.

Portable Modified Atmosphere Packaging Unit

The portable modified atmospheric packaging unit designed and developed in the Department of Processing and Food Engineering, CAE, UAS, Raichur was used for packaging the selected grains in one kg packets. The portable MAP unit consisted of a MAP box, top cover, nozzle, solenoid valve with time, pressure regulator, control panel, working table and CO_2 cylinder. The complete unit was enclosed in a grain holding box made of compressed ply wood. The said material was selected to reduce the cost and increase the strength of the unit. The flow of gas inside the packet is controlled by solenoid valve using the timer. The commercial carbon dioxide cylinder was attached to the unit which is commonly available in the market.

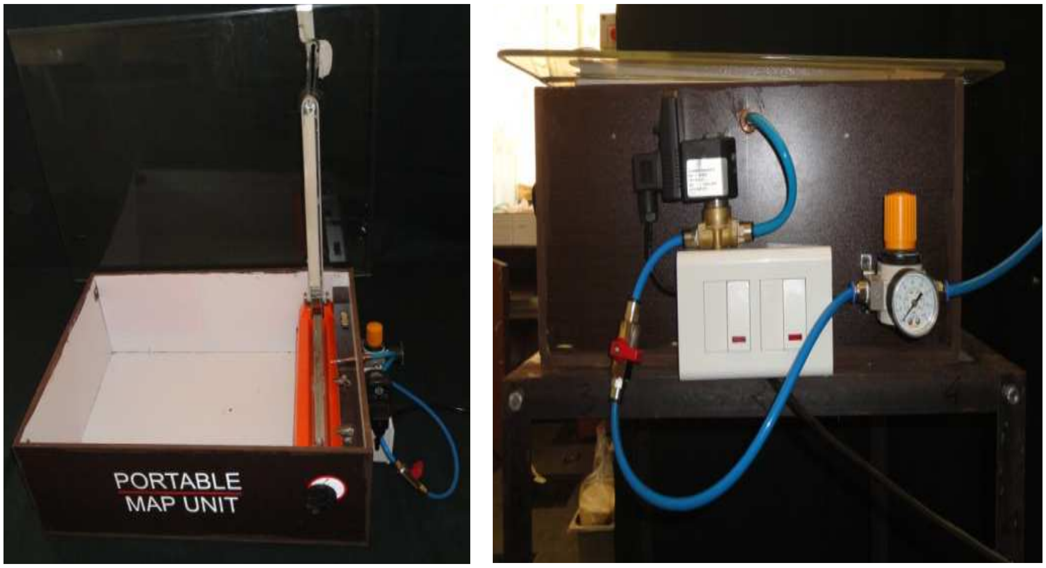

Figure 2.1: Portable Modified Atmosphere Packaging Unit

Optimization of CO_2 Flushing Pressure and Time for Selected Grains

The portable MAP unit was operated to flush the gas inside the packaging material at specified pressure and time so as to fill maximum CO_2 composition inside the packet. The target gas concentrations for insect toxicity are 3% or less O_2 and 60% or more CO_2 (Mbata *et al.,* 2004). Different pressure and time combinations were selected to achieve the target composition and interaction of both parameters were taken into consideration for optimization process.

The flushing was carried out at three different selected pressures *viz*., 2, 3,4 kg/cm^2 for sorghum and fourth pressure was included as 5 kg/cm^2 for Bengal gram so that maximum filling of carbon dioxide was achieved without spill over of grains from packaging material. Four different time intervals *viz*., 5, 10, 15, 20 s were selected based on preliminary study to flush the gas inside one kg packaging material to obtain the required composition inside the packet.

Statistical Analysis

Statistical analysis was carried out to study the effect of different parameters on all the dependent variables by asymmetric General Factorial Design (GFD). Two independent factors *viz.,* flushing pressure and time were used at four levels each and the degree of freedom for the experiment was 16. Analyses of variance (ANOVA) were calculated to determine whether significant effect of the flushing pressure and flushing time exists on the gas composition. The optimization was carried out using the optimization tool of the statistical software with two responses in the rage.

Responses

R1 – CO_2 maximization >60 %

R2 - O_2 minimization <3 %

Gas Composition in the Packages

The different gas composition of packaged grains were be determined by using head space gas analyzer for every month and for all the three commodities.

Seed Quality Parameters

Per Cent Insect Damage

About 100 seeds from each replication were drawn at random from each treatment. The damage of seeds attributed to insects was recorded by observing the infested and uninfected seeds manually. The damaged seeds with holes, eggs or both were counted as infested seeds and expressed in percentage on number basis.

$$\text{Per cent insect damage} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds observed}} \times 100$$

Germination

Germination test was conducted according to ISTA, 2013. Four replicates of 100 seed each in the germination paper medium and kept in the walk-in germination room. The germination room was maintained at 25±1°C temperature and 90±2% RH. At the end of sixth day after placing the seeds, the number of normal seedlings in each replication was counted and the germination was calculated and expressed in percentage.

Root Length (cm) and Shoot Length (cm)

From the germination test, ten normal seedlings were selected randomly in each treatment from all the replication on 6^{th} day. The root length of each seedling was measured from collar region to the tip of primary root and shoot length was measured from the base of primary leaf to collar region.

Seedling Vigour Index-I

The seedling vigor index was computed using the formula suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

Vigor index I = Germination percentage x Mean length of seedlings (cm)

Where, seedling length was measured from tip of shoot to root tip

RESULTS AND DISSCUSSIONS

Physical Properties of Selected Food Grains

The properties *viz.*, bulk density, particle density and porosity of grains were determined for rice, Bengal gram and sorghum and results are presented in Table 3.1.

Table 3.1: Physical Properties of the Selected Grains

S. No	Properties	Bengal Gram	Sorghum
1.	Bulk density, (kg/m^3)	818	821
2.	Particle density, (kg/m^3)	1330	1304
3.	Porosity, (%)	38.47	37.03

Selection of Packaging Material

The dimensions of the packet were selected based on bulk volume and head space required for gas filling. The dimensions of the packaging materials are presented in Table 3.2.

Table 3.2: Properties of Selected Packaging Materials

		Size (mm^2)	Thickness (mm)	Water Capacity (cm^2)
1)	PP	203×305	0.10125	1740
2)	PET	203×305	0.10375	1770
3)	LDPE	203×305	0.10625	1890

Optimization of CO_2 Flushing Pressure and Time for Selected Grains

The desirability test was conducted using design expert statistical software and flushing pressure and time for each grain was optimized for one kg retail packets. Desirability test was conducted for optimization of operating parameters with the optimization tool by fixing the responses R1 (CO_2>60%) and R2 (O_2<3%) in range.

From desirability test we observed that the flushing of CO_2 at 5 kg/cm^2 pressure for 10 second was having 97.8 per cent desirability of flushing for one kg Bengal gram packets and flushing of CO_2 at 2 kg/cm^2 pressure for 20 second was having 99.2 per cent desirability of flushing for one kg sorghum packets.

Carbon Dioxide Retention

CO_2 concentration was observed to be declining with increasing storage period for all the commodities. It was observed that CO_2 composition inside the packages reduced and attained the atmospheric condition within one month of storage in LDPE and PP packets for all the commodities, whereas PET retained higher levels of CO_2 for three months. The graphical representation of the decline presented in Figure 3.1, 3.2.

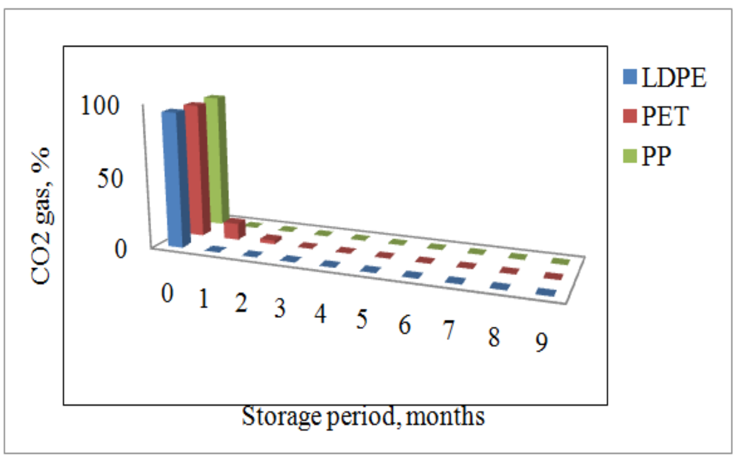

Figure 3.1: CO_2 Gas Retention for Bengal Gram

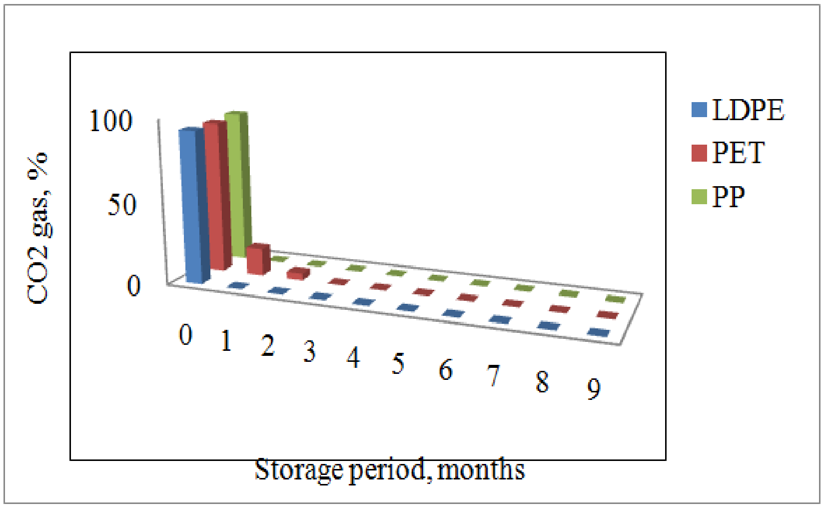

Figure 3.2: CO_2 Gas Retention for Sorghum

Quality Parameter

Percent Insect Damage

Per cent insect damage increased with the advancement of storage period and is shown in Figure 3.3 and 3.4. It was observed that in all the grains the incidence of insects was nil up to fifth month. The infestation was observed from sixth month onwards in LDPE and PP packages for all the grains whereas, no incidence of infestation in PET even at the end of nine month. The results are in agreement with Ramesh babu *et al.* (1991) and Press and Flaherty (1973).

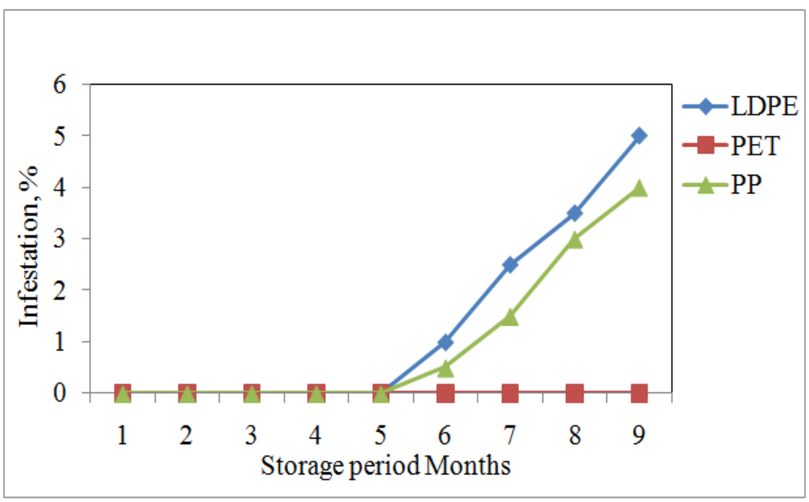

Figure 3.3: Percent Insect Damage with Storage Period for all the Packages of Bengal Gram

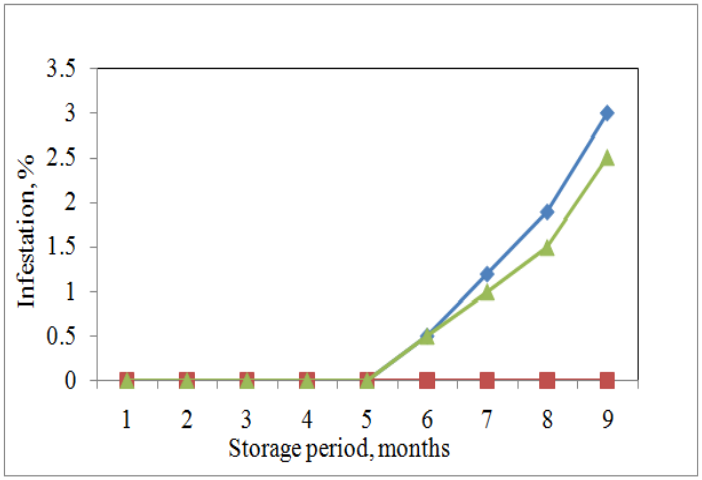

Figure 3.4: Percent Insect Damage with Storage Period for all the Packages of Sorghum

Seed Germination (%)

The results of germination percentage as influenced by modified atmospheric storage conditions and packaging materials during storage are shown in figure 3.5 and 3.6. Mean Seed germination declined with the advancement of storage period. It was observed that seed germination was highest for bengal gram stored in PET packets which is 100 per cent at initial stage and decreased to 97.5 per cent at the end of nine month of storage whereas, in LDPE and PP packages it declined from 100 per cent to 94.0 and 94.5 per cent respectively at the end of nine months of storage. Similarly for Sorghum seeds It was also observed that seed germination for stored in PET packages was 95.5 per cent at initial stage and decreased to 89.0 per cent at the end of nine months of storage where as in LDPE and PP packages it declined to 84.0 and 84.55 per cent at the end of nine months of storage. The probable reason for differences in longevity of seeds in the modified atmospheric storage conditions might be due to the higher concentration of carbon dioxide. Germination was reported to decrease in peas with increase in oxygen level (Roberts and Abdalla, 1968).

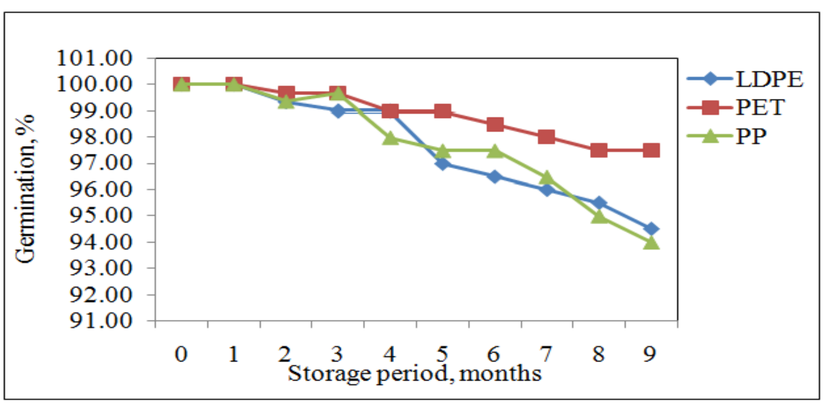

Figure 3.5: Germination Per Cent for Bengal Gram Packed in LDPE, PP and PET Packages

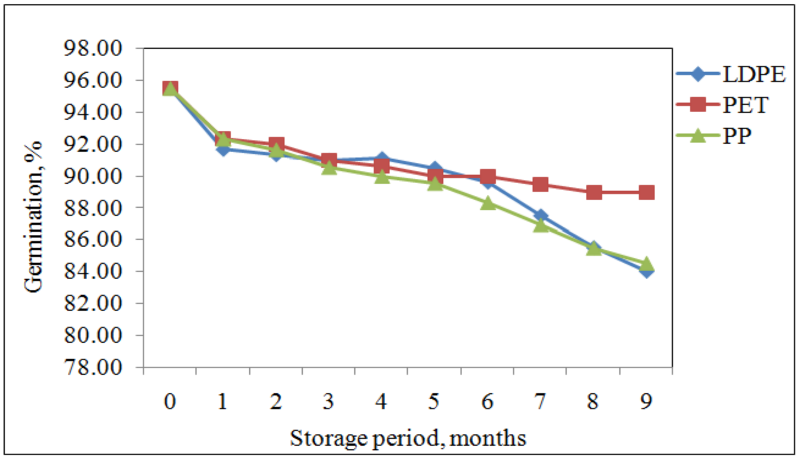

Figure 3.6: Germination Per Cent for Sorghum Packed in LDPE, PP and PET Packages

Seedling Vigour Index

The results of mean seedling vigour index as influenced by modified atmospheric storage conditions and packaging materials during storage are shown in figure **3.8 and 3.9.** Mean Seed germination declined with the advancement of storage period. The mean seedling vigour index for Bengal gram is highest with 2738 for PET after nine months of storage followed by PP with 2551 and LDPE with 2521. Sorghum also shown highest value of 2247 for PET followed by PP and LDPE with 2200 and 1945 respectively after nine months of storage.

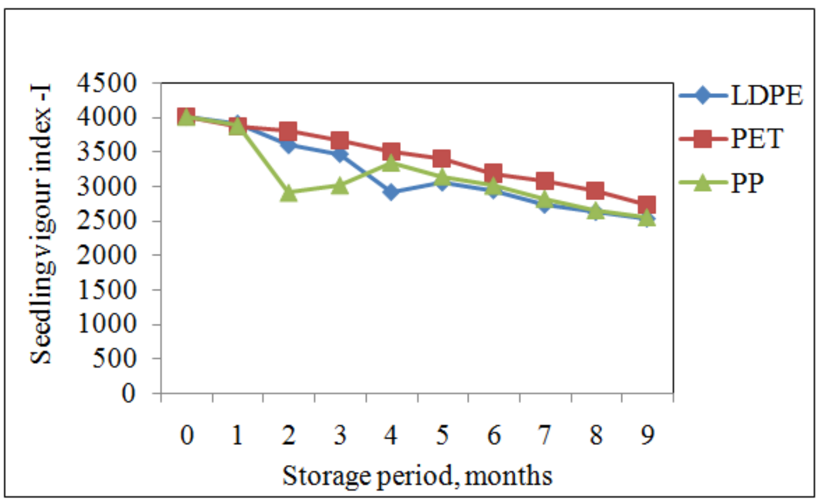

Figure 3.7: Vigour Index of Bengal Gram Packed in LDPE, PP and PET

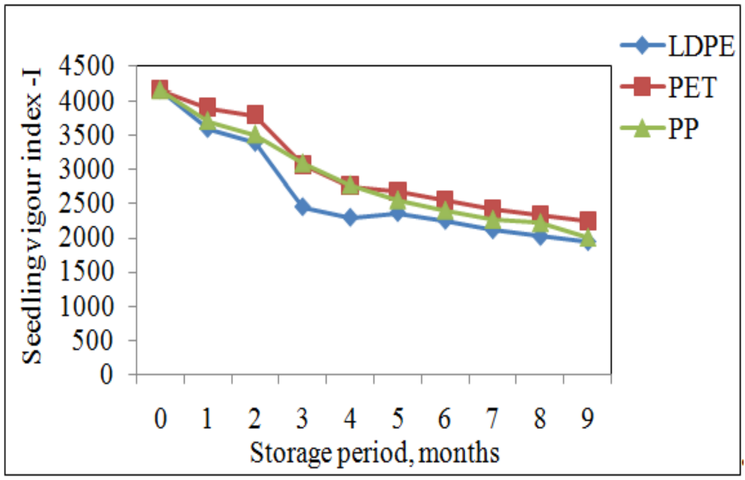

Figure 3.8: Vigour Index of Sorghum Packed in LDPE, PP and PET

CONCLUSIONS

MAP unit was evaluated for its performance against Bengal gram and sorghum during nine months storage period. The operational parameters of the developed portable modified atmospheric packaging unit *viz.,* flushing pressure and time were optimized for two different grains for maximizing CO_2 and minimizing the O_2 concentration using the statistical software. The desirability was higher at 5 kg/cm^2 pressure for 10 second for Bengal gram (97.8%) and 2 kg/cm^2 pressure for 20 second for sorghum (99.2%). The grains packaged after flushing with CO_2 were kept for shelf life study for a period of nine months and different quality parameters were studied. It was observed during storage that CO_2 gas retention was higher than the atmospheric gas composition in PET packages even after second months but in case of LDPE and PP packages the composition attained atmospheric condition within one month of storage for all the grains. In this study, all the seed quality parameters are decreased with the advancement of the storage period. This may be due to natural ageing of the seeds, increased membrane permeability. It was observed that seed quality parameters differ for different packaging materials. This may be due to impermeability packaging materials. Seed quality increased with impermeability of packaging (Almeida *et al*., 1997). This modified atmosphere packaging has been shown to be promising in creating lethal conditions for insects in stored commodities. It is best alternative methods to use of chemical for storage and don’t have any negative effect on seed quality parameters.

ACKNOLEDGEMENT

This work was supported by department of Agricultural processing and food engineering, college of agricultural engineering, UAS Raichur. The authors acknowledge Mr. Basavaraj patil, M.Tech graduate, Tamil nadu agricultural university for his help while writing this paper.

REFERENCES

1. *Abdul-Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria. Crop science, 13(6), 630-633.*
2. *Annis, P. C. 1987. Towards rational controlled atmosphere dosage schedules: a review of current knowledge. pp. 128-148. Donahaye, E. and S. Navarro (eds.). Proceedings of the 4th International Working Conference on Stored Product Protection. Tel Aviv, Israel.*

3. *Bailey, S. W. and Banks, H. J., A review of the recent studies of the effect of controlled atmosphere on stored-product pests. In: controlled atmosphere storage of Grains (ShejbalJ, Ed). pp 101-118Elsevier Scientific Publishing Co. Amsterdam, Germany. (1980).*
4. *Banks, J. and Fields, P. Physical methods for insect control in stored-grain ecosystems (Jayas D S; White N D G: Muir W E, eds), pp 353-410. Marcel Dekker, Ink., New York. (1995).*
5. *Bera, A., Sinha, S. N., G-aur, A., & Srivastava, C. (2008). Effect of modified atmosphere storage on seed quality parameters of paddy. Seed Res, 36(1), 56-63.*
6. *Church, N. (1994). Developments in modified-atmosphere packaging and related technologies. Trends in food science & technology, 5(11), 345-352.*
7. *Conyers, S. T., & Bell, C. H. (2007). A novel use of modified atmospheres: storage insect population control. Journal of Stored Products Research, 43(4), 367-374.*
8. *Edwards, G. A., 1953, Respiratory metabolism. In: Insect Physiology, pp.96-146.*
9. *Jay, E. G., Arbogast, R. T., & Pearman, G. C. (1971). Relative humidity: its importance in the control of stored-product insects with modified atmospheric gas concentrations. Journal of Stored Products Research, 6(4), 325-329.*
10. *Jayas, D. S., & Jeyamkondan, S. (2002). PH—postharvest technology: modified atmosphere storage of grains meats fruits and vegetables. Biosystems engineering, 82(3), 235-251.*
11. *Mangaraj, S., Agrawal, S., & Gandhi, A. P. (2005). Studies on physico-chemical changes in selected fruits during storage. Beverage Food World, 32(11), 72-75.*
12. *Mbata, G. N., Phillips, T. W., & Payton, M. (2004). Mortality of eggs of stored-product insects held under vacuum: effects of pressure, temperature, and exposure time. Journal of economic entomology, 97(2), 695-702.*
13. *Mitcham, E., Martin, T., & Zhou, S. (2006). The mode of action of insecticidal controlled atmospheres. Bulletin of Entomological Research, 96(3), 213.*
14. *Mohsenin N. N. (1986) Physical Properties of Plant and Animal Materials. New York: Taylor and Francis. [This book presents details on density, porosity, surface area, sphericity and roundness].*
15. *Moreno-Martinez, E., Jiménez, S., & Vázquez, M. E. (2000). Effect of Sitophilus zeamais and Aspergillus chevalieri on the oxygen level in maize stored hermetically. Journal of Stored Products Research, 36(1), 25-36.*
16. *Navarro, S., Dias, R., & Donahaye, E. (1985). Induced tolerance of Sitophilus oryzae adults to carbon dioxide. Journal of Stored Products Research, 21(4), 207-213.*
17. *Nicolas, G., and D. Sillans. 1989. Immediate and latent effects of carbon dioxide on insects. Annual Review of Entomology 34: 97-116.*
18. *Press, J. W., & Flaherty, B. R. (1973). Reduction of fecundity and egg hatch in three stored-product phycitid moths after repetitive sublethal carbon dioxide exposures. Environmental Entomology, 2(1), 147-148.*
19. *Rameshbabu, M., Jayas, D. S., & White, N. D. G. (1989). Design and fabrication of a controlled atmosphere unit for laboratory studies on control of stored product pests. Paper-American Society of Agricultural Engineers (USA). no. 89-6033.*
20. *Rameshbabu M; Jayas D S; White N D G (1991). Mortality of Cryptolestes ferruginous (Stephens) adults and eggs in elevated carbon dioxide and depleted oxygen atmospheres. Journal of Stored Product Research, 27(3), 163–170.*
21. *Roberts, E. H., & Abdalla, F. H. (1968). The influence of temperature, moisture, and oxygen on period of seed viability in*

barley, broad beans, and peas. Annals of Botany, 32(1), 97-117.

22. *Shepherd, H., & Bhardwaj, R. K. (1986). Moisture-dependent physical properties of pigeon pea. Journal of Agricultural Engineering Research, 35(4), 227-234.*
23. *Shejbal, J. De. K, and Boislambert, J. N., Modified atmosphere storage of grains. In: Preservation and storage Grains, Seeds and their By-Products: Cereals, Oilseeds, Pulses and Animal feed (Multon J L, ed), pp 749-777. Lavoisier Publishing Inc., New York. (1988).*
24. *Singh, P. K. (2010). A decentralized and holistic approach for grain management in India. Current science, 99(9), 1179-1180.*
25. *Verma, A. K., & Wadhi, S. R. (1978). Susceptibility of walnut pests to carbon dioxide and nitrogen and effect of gas storage on keeping quality of walnut kernels. Indian journal of entomology.*
26. *White, N. D. G., Jayas, D. S., & Sinha, R. N. (1990). Carbon dioxide as a control agent for the rusty grain beetle (Coleoptera: Cucujidae) in stored wheat. Journal of economic entomology, 83(1), 277-288.*